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Review of NASA's (National Aeronautics and Space Administration) Numerical Aerodynamic Simulation Program

National Research Council, Washington, DC

Prepared for

National Aeronautics and Space Administration
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16. Abstract (Limit: 200 words)

NASA has planned a supercomputer for computational fluid dynamics research since the mid-1970's. With the approval of the Numerical Aerodynamic Simulation Program as a FY 1984 new start, Congress requested an assessment of the program's objectives, projected short- and long-term uses, program design, computer architecture, user needs, and handling of proprietary and classified information. Specifically requested was an examination of the merits of proceeding with multiple high speed processor (HSP) systems contrasted with a single high speed processor system.

The panel found NASA's objectives and projected uses sound and the projected distribution of users as realistic as possible at this stage. The multiple-HSP, whereby new, more powerful, state-of-the-art HSP's would be integrated into a flexible network, was judged to present major advantages over any single HSP system. However, NASA's plans for user access thus far had focused on on-site users and the panel discerned a need to emphasize a long-haul communication system and needs of remote users. The study also expresses an urgent need for NASA and the DoD to agree on requirements for a secure facility...

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Review of NASA's Numerical Aerodynamic Simulation Program

Committee on NASA Scientific and Technological Program Reviews
Commission on Engineering and Technical Systems
National Research Council

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Prepared by a Panel Convened by the
Committee on NASA Scientific and Technological Program Reviews
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Review of NASA's Numerical Aerodynamic Simulation Program

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Preface

The Committee on NASA Scientific and Technological Program Reviews was created by the National Research Council in June 1981 as a result of a request by the Congress of the United States to the National Aeronautics and Space Administration that it establish an ongoing relationship with the National Academy of Sciences and the National Academy of Engineering for the purpose of providing an independent, objective review of the scientific and technological merits of NASA programs whenever the Congressional Committees on Appropriations so direct.[1]

When a review is requested, the committee is called on to set the terms of reference, select a panel of experts to carry out the task, and review the resulting report before publication.

To date, three tasks have been undertaken: reviews of the International Solar Polar Mission,[2] NASA's Aeronautics Program,[3] and the Space Shuttle Program.[4]

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[1]Congressional Conference Report 96-1476, November 21, 1980.

[2]National Research Council, The International Solar Polar Mission--A Review and Assessment of Options, 1981, National Academy Press, Washington, D.C.

[3]National Research Council, Aeronautics Research and Technology--A Review of Proposed Reductions in the FY 1983 NASA Program, 1982, National Academy Press, Washington, D.C.

[4]National Research Council, Assessment of Constraints on Space Shuttle Launch Rates, 1983, National Academy Press, Washington, D.C.

The fourth task, which is the subject of this report, resulted from a request by the Congressional Committees on Appropriations to the NASA Administrator in late June 1983 for an assessment of NASA's Numerical Aerodynamic Simulation Program. This program encompasses a new, large scientific computational capability for numerically solving aerodynamic problems and its related facilities, management, and operation. Specifically asked for was a review of the objectives, implementation, and several user-related issues of the program.

The committee met on July 20, 1983, to establish terms of reference for the review based on the Congressional request and to nominate a panel to undertake the task. The areas of expertise sought included computational fluid dynamics, computer science and technology, and design of aerospace systems.

In appointing such a group of individuals to make scientific and technical assessments, it is essential that most have a high degree of knowledge in the subject of the study. Since such individuals may appear to have a potential for bias, every effort was made to achieve a balance in backgrounds and attitudes of the panelists in order to present as objective a report as possible.

The committee wishes to record its appreciation to the chairman and members of the panel for their effective and timely response to the charge put to them.

Norman Hackerman
Chairman, Committee on NASA Scientific and Technological Program Reviews

I Introduction

THE DISCIPLINE

Computational aerodynamics is the simulation of aerodynamic flow fields by numerical solution of the fluid dynamic equations using high-speed computers. In the past decade, great strides have been made in computational aerodynamics as a result of improvements in numerical techniques and in the processing speed and storage capacity of new supercomputers. These advances are today making computational aerodynamics a powerful tool, complementing wind tunnels, for the design of new aerospace systems.[1] The experience gained to date concerning the impact of computational aerodynamics has served to create a vision of major improvements in air vehicle design to be gained with the emergence of tomorrow's more powerful supercomputers.

HISTORICAL BACKGROUND

The Numerical Aerodynamic Simulation Program (NAS) had its genesis in the mid-1970s when NASA began efforts to determine the feasibility of constructing a computer capability powerful enough--1 billion floating-point operations per second and 256 million words of memory--to solve routinely the fluid dynamic equations governing

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[1]National Research Council, 1983, Influence of Computational Fluid Dynamics Upon Experimental Aerospace Facilities: A Fifteen Year Projection, National Academy Press, Washington, D.C., pp. 1, 2.

the flow about aerospace vehicles. The perceived need was to provide a pathfinding capability that would serve to enhance the application of computational fluid dynamics to aerospace design. Such a computational capability was not then envisioned as becoming available in the commercial marketplace in the near future. In 1978 a User Steering Group was formed (later called User Interface Group) with members from the aerospace industry, universities, and other government agencies to provide an interface between NASA and potential outside users of NAS.

CURRENT STATUS

A reevaluation of the NAS program was made in 1982. At that time, NASA-contracted studies led the agency to discontinue the procurement process that was based on construction of a special system. It was deemed that the risks involved in achieving the proposed technical objectives within the critical resource and schedule limitations were unacceptable.[2] At the same time, a renewed interest in industrial development of supercomputers occurred as a result of a perception of a growing commercial market for their use. ETA Systems, Cray Research Inc., Denelcor, Hitachi, Fujitsu, and NEC are all in the process of developing supercomputers aimed at this market. This industrial surge has made it possible for NASA to achieve its 1975 objectives by acquiring off-the-shelf supercomputers rather than by assuming the technical risk of sponsoring the development of the next generation U.S. scientific computer.

In view of these developments, the NAS program was redefined to be an ongoing program in which advanced state-of-the-art high-speed processors (HSPs) would be acquired and coupled to a processing system network designed to accommodate them. This flexibility allows

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[2]National Aeronautics and Space Administration, "Numerical Aerodynamic Simulation Program Plan," Revised October 1, 1983, NASA Ames Research Center, Moffett Field, Calif.

upgrading of the system as improved mainframe computers are commercially developed, without NASA's becoming captive to any single vendor.

In its new form, the role of the NAS is that of: a continuing pathfinder in advanced, large-scale computing focused on computational aerodynamics; a strong research tool; and a national computing facility available to NASA, DoD, other government agencies, industry, and universities. This concept has been endorsed by the aeronautics community, by those in other disciplines involving fluid dynamics research, and by the federal government. The initial performance goals in this new role call for a computer system capable of 250 million floating-point operations per second (MFLOPS) with direct access to 64 million words of main memory by late 1984 or early 1985 and an additional system capable of 1000 MFLOPS with 256 million words of main memory in 1987--the original NAS objective but now achievable with commercially developed equipment.

In its budget submission for FY 1984, NASA requested $20 million for the first year of the NAS program, including plans for a time-share lease of a Cyber 205 and for lease of a Cray-2 prototype HSP. In early 1983 the NAS was approved by Congress and the Administration as a NASA "new start" for FY 1984 with the restriction that only one HSP be acquired and the funding was correspondingly reduced to $17 million. Since approval, an NAS Project Office has been established with the appointment of key personnel, and detailed elements of the program are being developed.

Following a request by the Congressional Committees on Appropriations (Appendix A), the Committee on NASA Scientific and Technological Program Reviews (Appendix B) nominated a panel to undertake the study and established guidelines to the Panel (Appendix C) to provide the following:

- an examination of the stated objectives of the program including the projected short- and long-term uses of the system

- an examination of the projected distribution of users and user requirements

- the merits of proceeding with a multi-processor system, a single processor, or some alternative architecture in terms of system capability and meeting user requirements

- an examination of provisions to make the system readily and easily accessible to the intended users

- milestones necessary to optimize a processing system network whether a multi-processor, single processor, or some alternative architecture is used, and

- an examination of NASA's plans for the handling of proprietary and classified computations and their anticipation for downtime.

II Approach

The panel met in Washington, D.C., on September 1, 1983, and received preliminary briefings from NASA headquarters staff. On September 2 panel members prepared a list of 25 salient questions regarding design and implementation of the NAS Program for NASA review and response. In addition, assignments were made to various members of the group to investigate several aspects of the operation of other major computational centers. Individuals visited the Magnetic Fusion Energy Computer Center and the Livermore Computer Center on September 15, 1983; the Computational Fluid Dynamics Group at the Air Force Wright Aeronautical Laboratories on October 13, 1983; and met with representatives of Control Data Corporation and Cray Research, Inc. in the San Francisco Bay area on January 9, 1984.

The second meeting was held at the NASA Ames Research Center on November 2-4, 1983, and the NAS program management spent two days briefing the members of the panel, responding to the questions posed earlier, and participating in extensive discussions. This study was conducted during a period of high-level NAS managerial planning. Every effort was made by both the panel and NASA to assure that the exchange was useful.

Between the second and third meeting, panelists conducted further investigations and prepared drafts that were distributed in advance of the last meeting. These drafts were reworked, and consensus was reached on the contents of the report at the final meeting on January 19-20, 1984.

NASA representatives and contractors who met with the panel are listed in Appendix D. Appendix E lists the User Interface Group. Appendix F is a list of specific briefings to the panel, and Appendix G contains NASA's

master milestones schedule. Appendix H is a letter from the Director of Astronautics, NASA Ames Research Center, detailing actions taken and plans made subsequent to the panel's visit to the Center.

III Objectives

The objectives of the NAS program as stated in the NAS Program Plan dated October 1, 1983, are to:

(a) Act as the pathfinder in advanced, large-scale computer system capability through systematic incorporation of state-of-the-art improvements in computer hardware and software techniques.
(b) Provide a national computational capability, available to NASA, DoD, industry, other government agencies, and universities, as a necessary element in insuring continuing leadership in computational fluid dynamics and related disciplines.
(c) Provide a strong research tool for NASA.

The panel endorses the objectives of the NAS. While the pathfinder concept, objective (a), is here associated with supercomputer capability, in truth the association is more properly with the entire NAS--hardware, facilities, software, and algorithms--and its role in furthering progress in computational fluid dynamics (CFD). Objective (a) is especially important because the NAS, as pathfinder, will provide a host for the implementation of new methods and capabilities of computational aerodynamics; will be used to provide demonstrations to the aerospace industry of capabilities requiring the use of the most advanced computers; will enable industry to make earlier and lower-risk decisions concerning their own acquisition of large-scale scientific computers; and will provide a test bed for demonstration of the effectiveness

of the various elements of the computational system in enhancing productivity. Objective (b), to provide the most powerful computational capability possible, is consistent with the 1958 Space Act which charges NASA with "improving the usefulness, performance, speed, safety and efficiency of aeronautical and space science technology" and the "preservation of the role of the United States as a leader in aeronautical and space science technology." Objective (c) is seen as an essential element in the development of future stages of CFD technology for the aerospace community in general and for use in aircraft design in particular.

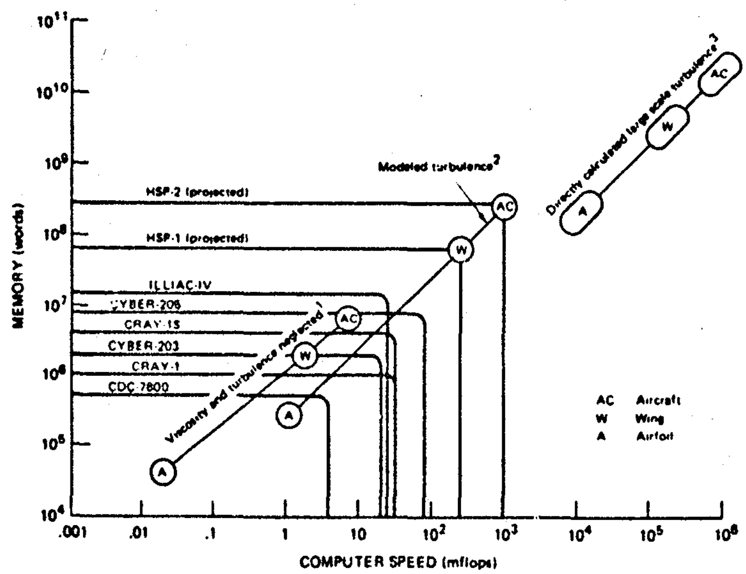
Specifically, the panel is in agreement with the following objectives in the NAS Program Plan to:

> . . . enable a large number of users from NASA, DoD, academia and industry to simultaneously solve heretofore intractable problems . . . NAS will play a powerful pathfinding role in all four phases of aeronautical R&D: (1) Basic Research where solutions of the full Navier-Stokes equations will reveal underlying mechanisms of turbulence, flow separation/reattachment and aerodynamic noise. This understanding will contribute to the design of quieter and more efficient aerospace engines and airframes required for future U.S. aerospace superiority. (2) Preliminary Designs will be possible for a much larger number of candidates and in more technical depth than currently possible. This will lead to more refined initial designs before costly and time-consuming wind-tunnel testing begins. (3) Once these preliminary designs are validated by wind-tunnel tests, powerful optimization techniques will be applied for configuration refinement while simultaneously accounting for all components in combination (e.g., wing-fuselage-engine) thus eliminating undesirable interactions between components. (4) Design Verification by numerical simulation of full-scale performance throughout the full flight envelope will be accomplished before prototype fabrication. This then will be the modern approach to aeronautical R&D where the computer system optimally carries the burden of the research and design with verification by wind-tunnel testing.

SHORT- AND LONG-TERM USES

The panel reviewed the intended uses of the NAS Program. The present focus of computational research with the NAS lies in two areas. One is to develop and refine numerical techniques for solving the time-averaged fluid dynamic equations wherein turbulence is empirically modeled--the Reynolds-averaged Navier-Stokes equations. This level of capability is the next major stage in applied computational aerodynamics, and the generation of computers representative of the first HSP--and the growth versions--will provide a level of computer power that will enable the application of this new capability to practical design problems for aerospace vehicles. The second focus is on computational research for solving the full nonsteady fluid dynamic equations with direct computation of large-scale turbulent motion--large-eddy simulation. This advance will pave the way for another major increase in capability in computational aerodynamic applications with the emergence of later generations of HSPs in the 1990s and beyond. Performance and memory requirements for these stages of development of computational aerodynamics are compared with several generations of high-speed computers in Figure 1.

The performance goal for NAS in 1987 has been appropriately set as that required to solve the Reynolds-averaged Navier-Stokes equations for the complex geometric configurations of aircraft. With that level of computer memory and speed, major research advances will also become feasible using large-eddy simulation technology. The panel believes that the intended uses of NAS are compatible with the level of HSP computer power that will be available and that these uses represent the most effective exploitation of the NAS.



1. Fluid dynamic equations without viscous terms or modeled turbulence.

2. Reynolds-averaged Navier-Stokes equation with modeled turbulence.

3. Navier-Stokes equations with large eddy simulation and modeling of small-scale turbulence.

Figure 1 Computer Speed and Memory Requirements Compared with Computer Capabilities (15-minute runs with 1985 Algorithms)

Basic figure courtesy Dean Chapman and NASA

IV NAS Program Design and Computer Architecture

BRIEF DESCRIPTION

The computational system of the NAS Program--called the NAS Processing System Network (NPSN)--consists of (1) the high-speed processors (HSP) and (2) network peripheral systems which provide the interface between the user and the processor. The elements of the NPSN are shown in Figure 2. One of the major elements will be the mass storage subsystem; it will include an on-line system with at least 200 billion characters of storage, expandable to 800 billion characters.

The NAS Program is designed around the acquisition of the most advanced HSP systems available from the computer manufacturers. The initial HSP (HSP-1) is expected to be the prototype Cray-2. In the long term, NASA proposes to have two HSPs, one being mature and fully operational, and the other, a new, higher performance one--a prototype or early production model. The NPSN would be designed with the flexibility to accommodate HSPs, possibly with different architectures* and vendors, in a way that is user friendly.

In its Initial Operating Configuration the NPSN will be housed temporarily in existing facilities at the Ames Research Center. In the longer term, referred to as Extended Operating Configuration, the NPSN and supporting activities would be housed in a new Numerical Aerodynamic Simulation Facility (NASF) estimated to cost $17 million, not including provision for security features needed to handle classified work.

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*Computer architecture is a schema of what the major parts of a computer are, what they do, and how they work together.

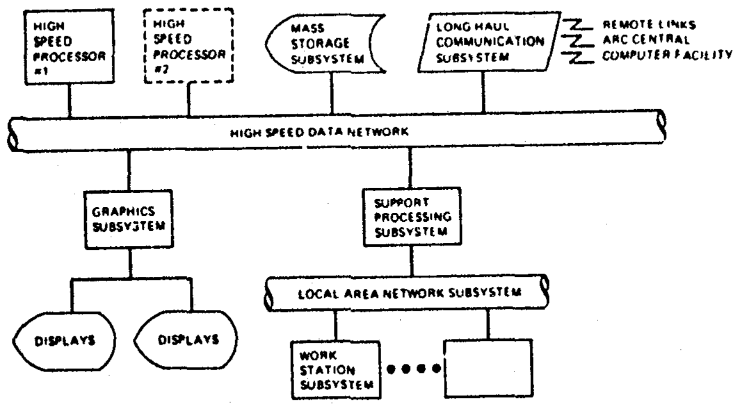

Figure 2 The NAS Processing System Network (NPSN). (Courtesy of the National Aeronautics and Space Administration.)

THE MULTIPLE-HSP ISSUE

The panel was asked to consider the issue of whether the NAS should consist of a single or more than one HSP. In addition to complexity and cost, several different factors must be taken into account in addressing this issue:

1. Considerably greater computer capabilities than those available in the immediate future are needed to exploit the potential of computational aerodynamics.
2. The speed and memory size of high-speed computers have increased by a factor of 10 per decade during the past 30 years, and this rate of growth is projected to continue in the foreseeable future.[3]
3. A mature computational capability should be available on an uninterruptible basis to maximize the opportunity to make advances in computational aerodynamic research and applications.
4. New, advanced computer systems require a shakedown and evaluation period before they can become fully operational and useful.

The Single HSP Approach

The NSPN with a single HSP has a somewhat lower initial cost than the multiple-processor approach envisioned by NASA. However, the performance of the HSP would be surpassed every few years by a new generation of supercomputers. Thus, to maintain the pathfinder role, the NAS must periodically acquire a new processor at an early stage of its availability, and substantial amounts of time and effort must be invested to bring it to operational status. Depending on the upward compatibility of the new processor with the existing one, past experience has established that a year or more is required to accomplish effective integration. During this period, there would be no operational HSP available to the user

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[3]National Research Council, Influence of Computational Fluid Dynamics, pp. 6-9

community. In addition, the architectures of various supercomputers can be quite different. Since the performance of CFD algorithms is often architecture-dependent, a single HSP configuration may be highly efficient for only a limited class of problems.

These considerations indicate that a single HSP configuration would severely compromise the concurrent fulfillment of the NAS Program objectives--pathfinder, national CFD capability, and research tool. To maintain the pathfinder role, NAS would not be able to provide a CFD capability for substantial periods of time to most of the user community listed in Chapter V. Outside users (DoD, industry, universities, and other NASA centers) would be most severely affected. Also, the availability of a secure capability for classified and proprietary work may be minimal under these conditions.

It appears that the lower initial cost will be more than offset by the penalties of a prolonged unproductive downtime when the processor requires updating. The panel believes that the objectives of NAS are proper and that a single HSP configuration cannot provide a capability to fulfill these objectives.

The Multiple-HSP Approach

NASA proposes a dual-HSP approach. This concept involves an HSP capability of two machines with provision for replacing the older of the two every few years with industry's most advanced HSP system as the pathfinder, irrespective of the vendor, as noted earlier under BRIEF DESCRIPTION.

It appears to the panel that a multiple-HSP approach offers the following advantages:

1. During a transition to a new HSP, there would be a mature HSP still on line to support ongoing CFD research and development, and the user community would continue to be served if one HSP were down for maintenance or modification. Furthermore, one HSP could be isolated for classified or proprietary work without affecting all users.
2. It will broaden algorithm research beyond the limitations of the architecture of one computer manufacturer, especially with regard to anticipated major architectural changes.

3. The NAS project will forge a strong technical community, rooted in-house but spanning the university and private sectors. The multiple-HSP approach permits this community to encompass multiple vendors, thereby providing a forum where computer manufacturers and algorithm developers together can acquire the knowledge needed to guide productive evolution of computers and solution algorithms.
4. It provides the early availability of different processor architectures, thus offering the flexibility to select the type of architecture most efficient for a particular application.
5. It will also allow performance comparisons of mainframe HSPs for specific CFD applications. Thus, it will advance the development of production-quality early application programs for those HSPs that will be acquired by the aerospace industry and other members of the external user community.

These merits must be understood in the context of the additional start-up costs involved. Extra costs arise from the need to provide a more general and flexible network from the start to accommodate the different vendors' architectures and to provide a user friendly interface. The control language, user languages, and the file system should all be compatible, regardless of mainframes. Much of the vendor-provided software may have to be modified or replaced to provide this compatibility. In this regard, standardizing the operating system at an early date should reduce these transition difficulties.*

The panel believes the two-processor approach currently planned for the NAS is the proper one and that the phased beginning is appropriate.

In the years following HSP-2, when a new supercomputer is procured, users must phase out of the old HSP by transferring their codes either to one of the other NAS HSPs or to a machine outside the NAS complex.

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*The present NASA plan is to use UNIX™, an operating system developed by Bell Laboratories.

Depending on machine availability and demand at the time, it may be necessary to retain the old HSP in the NAS complex until the transition has been completed.

SYSTEM RELIABILITY

The NAS will eventually have a very extensive network, including not only long-distance communications to support remote users but also an internal network of multiple large processors. It will, therefore, have to face the problems of reliability that are common to all such systems. Since the system at any one time may be supporting many tens of users, questions of its availability and reliability are of high importance. In a complex system such as NAS, compared with a traditional, stand-alone, simple, uniprocessor configuration, the question of restarting the system and recovering from a system collapse is correspondingly more difficult and is an essential issue for systems design. It cannot be assumed that whatever restart-recovery features exist in the vendor-supplied software will coordinate smoothly with one another when combined in an extensive network. Thus, at some point early in system design, consideration must be given specifically to the restart-recovery issue.

MILESTONES

Detailed development of NAS began in early 1983 when the program was approved. In November 1983 the panel reviewed the planning documents and preliminary milestones that were developed to permit the integration of the network system as soon as the first HSP is ready to be tied into it. The major milestones, as developed by NASA, appear in Appendix G. In the panel's view, they are appropriate only for the initial planning stages. Obviously, detailed planning documents and milestones for each portion of the network system are needed, and it is important that they be completed by mid-1984 if the system is to be fully operational by mid-1985.

V User Needs and Concerns

IDENTIFICATION OF POTENTIAL USERS

The users of the NAS are expected to be from NASA, the Department of Defense (DoD), other government entities, the aerospace industry, and universities.

The largest single user will be NASA, with computational fluid dynamics (CFD) research teams at Ames, Langley, and Lewis Research Centers totaling approximately 150 people. The largest concentration of potential users is at Ames Research Center, which has several branches concerned with CFD within both the Aeronautics and the Astronautics Directorates. The lead branches are within the Thermo- and Gas-Dynamics Division. In addition, the Research Institute for Advanced Computer Science was recently established at Ames. Langley has three branches concerned with CFD in their Aeronautics Directorate, as well as the Institute for Computer Applications in Science and Engineering. Lewis has CFD branches concerned with engine and inlet flows. While it is anticipated that 90 percent of NASA research computations will be in fluid dynamics, other disciplines include computational chemistry, structures, space science, and atmospheric modeling.

DoD's CFD effort is conducted at its research and development laboratories and by contractors. The Air Force has major programs at Wright Aeronautical Laboratories and the Arnold Engineering Development Center. CFD work is also done at Eglin Air Force Base, the Army Ballistics Research Laboratory, the Naval Underwater Systems Center, the David Taylor Naval Ship Research and Development Center, and the Naval Research Laboratory.

In addition to the DoD laboratories mentioned above, government entities with interest in a scientific supercomputer dedicated to CFD include the Scripps Institution

of Oceanography, the National Center for Atmospheric Research, the National Oceanographic and Atmospheric Administration, and the National Science Foundation.

Most aerospace airframe, rotorcraft, and engine manufacturers have an interest in optimizing aerodynamic designs using CFD methods before wind tunnel testing and development of prototypes. Many of these companies have in-house CFD groups that represent potential NAS users. Many major companies are represented on the NAS User Interface Group (Appendix E), which has been briefed on NAS planning and has provided advice regarding the program since 1978.

Across the country, important CFD research is being conducted independently at universities. NASA funds special CFD training grants at New York University and Princeton (joint project), Iowa State, Stanford, Massachusetts Institute of Technology, Pennsylvania State, and the universities of Arizona and Cincinnati. Among the other universities with substantial CFD research efforts are Case Western Reserve, Cornell, Mississippi State, North Carolina State, Polytechnic Institute of New York, Purdue, Rutgers, Virginia Polytechnic Institute, and the universities of Colorado, Maryland, and Washington.

AN EXAMINATION OF THE PROJECTED DISTRIBUTION OF USERS AND USER REQUIREMENTS

NASA anticipates that two-thirds of NAS usage will be for basic research and one-third for applications research. The projected distribution of usage estimated by NASA is as follows:

NASA	55%
Department of Defense	20%
Industrial	15%
Universities	5%
Other Government Agencies	5%

The estimated usage of NASA and DoD includes not only in-house work but also grants, contracts, and joint efforts with universities and industry. For example, as much as 10% of the 55% of the NASA allotment and 5% of the 20% of the DoD effort could actually be used by

universities on research projects supported by these agencies. The 15% usage by industrial interests would be cost reimbursed to the government.

These projections were developed by NASA. The panel believes that the main groups of possible users have been considered and that the estimated distribution of users is as realistic as can be expected before the fact.

User requirements reviewed by the panel included general requirements common to all users and requirements specific to certain groups of users. General requirements include:

- Adequate speed and memory of the HSPs
- Adequate mass storage
- Stable operating configuration
- User friendly operating system and terminal interface
- Assistance to users, including softwar documentation and library

Requirements specific to certain groups of users include:

- NASA users
  - Workstations and graphics terminals
  - Data links to NASA Langley and Lewis Centers
- DoD users
  - Long haul, high-bandwidth communications
  - Provisions for classified work
- Commercial users
  - Long haul, high-bandwidth communications
  - Provisions for classified work
  - Protection of proprietary material
- University users
  - Long haul, high-bandwidth communications

For the NAS to meet its planned objectives, it is essential that the overall system contain a very stable portion, comprising all components except the newest, most advanced HSP. That processor may at any time be in the process of installation, familiarization, or trial operation.

The panel found that NASA is cognizant of the user requirements and is developing or has moved to improve its plans for addressing all of them. The weakest links in the planning to date appear to be provisions for proprietary and classified work and for long haul communications for remote users (discussed below).

It is the opinion of the panel that the NAS system will be in high demand. Even with the most effective system design and implementation, it will be a challenge for NASA management to accommodate the potentially vast community of users.

The actual distribution of users will be established by evolution rather than by predetermined targets. This process will be heavily dependent upon how well the NAS program addresses user requirements. For example, depending on the costs and bandwidth of the long haul communications system, remote usage may either fall below or exceed projections. If secure operation is not available, certain DoD and industry usage will not materialize.

USER ACCESSIBILITY

The panel has examined the "provisions to make the system readily and easily accessible to the intended users," as requested in its charge, and believes that the NAS Processing System Network is designed to make the computational power of the HSPs as accessible as possible to the users. A standard user interface will be provided through UNIX or UNIX-like operating systems for file management, job control, and graphics. The difficulties for a user to move programs to more powerful HSPs as they become available will thus be alleviated. Here, as in this whole technical development, it is important to minimize software costs by using existing software where possible. As noted in the preceding chapter, the panel has reviewed carefully the basic concept of an NPSN designed to be relatively independent of the specific HSPs attached to it and agrees that it is the appropriate and efficient way of serving the NAS community of users.

Particular importance should be assigned to the long-term stability of the HSP-independent aspects of this user interface.

LONG HAUL COMMUNICATIONS

It appears that at this early stage in NAS planning the greatest attention has been given to the requirements of on-site users, as is, perhaps, to be expected. Yet, in

full operation, more than half the users will be at remote sites. These users will work either through other computing centers in NASA laboratories, industry, or large universities or will require individual access from smaller universities or research centers.

The pattern of remote use will be quite different from that on-site. In particular, the powerful work-stations being planned may be uneconomical for most remote access.

The planned long-haul communication system is a key element of any remote use. Communications technology is changing so rapidly that it is not clear whether the system of the future should be based on transmission by dial-up circuits, dedicated voice-frequency circuits, dedicated digital circuits, or packet digital connections. The initial long haul communication will be through more conventional dial-up or packet digital access.

The NAS Program Office is aware of such user needs and has, in the long-established User Interface Group, a mechanism for interacting with and responding to users' concerns. However, increased attention should be given soon to the special needs of remote users. The panel suggests appointment of a full-time staff member with responsibility for identifying the special problems of remote users and matching them to technologically feasible solutions.*

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*In the course of its review, the panel raised concern about the attention being paid by the NAS Program Office to long haul communications and remote-user access. NASA has recently directed additional personnel efforts to address these areas (see Appendix H).

VI The Handling of Proprietary and Classified Information

The NAS must operate securely not only for its own protection against such threats as malicious penetrators and unauthorized users, but also to afford appropriate safeguards for the handling of proprietary information and classified defense information. Many of the safeguards that will be required in order to have a facility certified to accommodate classified information will also be essential simply to protect an expensive, important national facility, e.g., physical and fire protection, access control to the NPSN, and personnel control.

This area of NAS planning has not been completed, and questions remain regarding requirements and facilities for proprietary and secure research. Most importantly, funding has not been allocated to provide for secure aspects of the NAS facility. A discussion of unique requirements for security and the panel's concerns about this issue follows.

PROPRIETARY INFORMATION

With regard to the handling of proprietary information, there is a range of options that the NAS could offer to industrial and defense users. A proprietary user could, for example:

- o fit his workload into the normal operational schedule of the facility and rely on routine safeguards of the system.
- o request that no other remote connections be attached to the facility at the time but otherwise insert his workload into the normal operational schedule.

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- insist that no work from a competing company be performed concurrently on the machine.
- insist that he have sole access to the facility at that time.
- insist that he have complete visual surveillance while his runs are being made in the facility.
- insist that his own operators--functioning under the surveillance of NAS personnel--conduct the runs.
- provide his own encryption protection.

Clearly, these options are not mutually exclusive, but suggest that a variety of approaches is possible in dealing with this issue. Each proprietary user's choice will certainly be determined by the threat that he perceives against his information, possibly by economic concerns, possibly by convenience concerns, and possibly also on the basis of urgency of access to the facility. The proprietary user should weigh the cost of any special arrangements requested against the importance and value that he attaches to the work. The panel believes it is important that cognizant NAS project personnel continue working with their counterparts in the aerospace industry to define mutually acceptable options and that NASA announce as soon as possible the provisions that will be made available to protect proprietary users.

CLASSIFIED INFORMATION

There is no corresponding range of options for the classified user. NASA representatives project that the NAS facility will function under DoD security regulations, and therefore will have to conform completely to such requirements. This would include such items as physical protection, clearance of personnel, protection of remote communications, a comprehensive administrative/procedural overlay to assure the satisfactory operation of such safeguards, and TEMPEST concerns. TEMPEST security includes such items as electromagnetic shielding, acceptability/nonacceptability of an external power supply, complete isolation (physical unplugging), and secure rooms for demountable or unpluggable mass storage devices. Special access programs, which are

becoming typical of today's classified work, impose a requirement for multiple secure rooms and multiple secure working facilities.

Classified runs will clearly require what is commonly called periods processing, implying that remote communication connections must be severed (except for the secure run itself if it is from a remote source); that the machine be stripped of all other work; and that after the completion of a classified run all temporary and permanent storage space used by the classified operation be satisfactorily erased or permanently protected. Obviously, if an approved classified run is conducted from a remote location, the normal encryption and communication security precautions will have to be taken.

The panel notes that, while there has been liaison between NASA and the DoD for some time, to date the extent of future DoD participation is uncertain. It had been anticipated by NASA that DoD would share the expenses of providing a secure area. Currently, NASA management plans a new building to house the NAS systems, one room of which will be reserved for classified installations. The need for multiple secure areas must be addressed in the facility plans.*

The panel recommends that NASA give attention to this issue and suggests that NASA and DoD expedite efforts to work together in defining an environment for the NAS that will provide the proper security safeguards. This output should enter into the facility plan prior to construction, but care should be taken not to delay construction of the facility. (At the present time, NASA estimates that appropriate security measures can be added during construction of the NAS facility for an additional cost of $2.5-$3.5 million. There is a question of whether NASA will seek partial funding from DoD or try to provide this additional funding itself.)

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*NASA is directing increased attention to security needs (see Appendix H).

A final concern voiced by the panel is that the conduct of classified work may preempt other research needs and especially the pathfinder role of NAS. However, the panel notes that NASA has established a high-level management team to handle allocation of time and regards this as an appropriate safeguard.

VII Summary of Findings

The objectives of the NAS--a national computational capability to serve government, industry, and universities--are sound, consistent with NASA's mission, and highly appropriate in light of the growing practical significance of computational aerodynamics in the design of aerospace systems (Chapter III).

The short- and long-term uses of the NAS are well conceived and focused to deal with increasingly more exact and, hence, more complex forms of the fluid dynamic equations (Chapter III).

The multiple-HSP approach, whereby new, more powerful, state-of-the-art, high-speed processors (HSPs) will be integrated into a flexible network system, presents major advantages over a single high-speed processor system. The approach currently planned for the NAS, a dual-HSP system, is a proper one, and a phased beginning is appropriate. A single-HSP configuration cannot provide a capability to fulfill the NAS objectives. Sufficient justification may arise in future years to make it desirable for the NAS to accommodate more than two HSPs at any given point in time (Chapter IV).

While preliminary milestones have been developed for the integration of the network system and HSP, it is important that detailed milestones for each portion of the network system be established by mid-1984 (Chapter IV).

The projected distribution of users--NASA, DoD, other government agencies, industry, and universities--is believed to be as realistic as can be expected at this time (Chapter V).

Regarding user needs, the NAS Processing System Network--high-speed processors and peripheral network

system--along with a standardized operating system appear appropriately planned and conceived. It is realistic to expect that a stable, reliable network processing system as envisaged will facilitate the users' transition from one HSP to another even though HSP architectures may differ. The importance of having a stable processing network when the NAS becomes operational cannot be overstated (Chapter V).

In the planning for user access to NAS, the greatest attention has been given thus far to the requirements of on-site users. However, when the NAS is fully operational, more than half the users will be at remote sites. Increased attention should be given soon to remote users' special needs, the key element of which is the long haul communication system. In this respect, the panel suggests that a full-time staff person be appointed with responsibility for identifying the special problems of remote users and matching them to technologically feasible solutions (Chapter V).

Regarding classified work, there is an urgent need for NASA and DoD to reach agreement on requirements for a secure facility. Protection of proprietary work requires additional planning and liaison with industrial users (Chapter VI).

APPENDIX A

United States Senate
COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

June 22, 1983

RECEIVED
JUL 5 1983

The Honorable James Beggs
Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Mr. Beggs:

While the Appropriations Committees are in general agreement about the desirability to develop a Numerical Aerodynamic Simulation (NAS) Program at the earliest opportunity, there are still a number of questions that arise regarding implementation of the program and future use of the system.

Therefore, in accordance with the relationship previously established between NASA and the National Academy of Sciences and the National Academy of Engineering, we would like to request a review of the Numerical Aerodynamic Simulation Program.

Specifically, we request that the National Research Council Committee on NASA Scientific and Technological Program Reviews establish a mechanism to examine the following:

- the stated objectives of the program and the projected short-term and long-term use of the system, projected distribution of users, and user requirements
- the merits of proceeding with a multi-processor system versus a single processor in terms of system capability and meeting user requirements
- provisions to make the system readily and easily accessible to the intended users
- milestones necessary to develop a processing system network to optimize a multi-processor or a single processor approach.

We request that this review be available no later than March 5, 1984.

Sincerely,

Edward P. Boland
Chairman
House HUD-Independent
Agencies Subcommittee

Jake Garn
Chairman
Senate HUD-Independent
Agencies Subcommittee

APPENDIX B

COMMITTEE ON NASA SCIENTIFIC AND TECHNOLOGICAL PROGRAM REVIEWS

NORMAN HACKERMAN, President, Rice University, Houston, Texas, Chairman
WILLIAM A. ANDERS, Executive Vice President--Aerospace, Textron, Inc., Providence, Rhode Island
RAYMOND L. BISPLINGHOFF, Director for Research and Development, Tyco Laboratories, Inc., Exeter, New Hampshire
GEORGE W. CLARK, Professor of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts
EUGENE E. COVERT, Professor of Aeronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts
ALEXANDER H. FLAX, President Emeritus, Institute for Defense Analysis, Alexandria, Virginia
RICCARDO GIACCONI, Director, Space Telescope Science Institute, Johns Hopkins University, Baltimore, Maryland
JOHN W. TOWNSEND, JR., President, Fairchild Space Company, Germantown, Maryland
HERBERT FRIEDMAN, Chairman, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, Washington, D.C., Ex-Officio Member
MARTIN GOLAND, Chairman, Commission on Engineering and Technical Systems, National Research Council, Washington, D.C., Ex-Officio Member

ROBERT H. KORKEGI, Executive Director
JOANN CLAYTON, Staff Officer
ANNA L. FARRAR, Administrative Assistant

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APPENDIX C

STATEMENT OF TASK

A REVIEW OF NASA'S NUMERICAL AERODYNAMIC SIMULATION PROGRAM

The National Academy of Sciences/National Academy of Engineering through the National Research Council contracted to furnish the National Aeronautics and Space Administration, through the NASA Chief Engineer, a review of the *Numerical Aerodynamic Simulation Program* in response to Congressional request. This study is the fourth task under a broader contractual arrangement with NASA to provide Congress with NRC reviews of proposed changes in NASA programs. In a letter dated June 22, 1983, from Senator Garn and Congressman Boland to NASA Administrator James Beggs, requesting the task, it was asked that a report be available to the House and Senate Appropriations Committees by March 5, 1984.

To deal with the request for carrying out reviews of NASA programs, the NRC established the Committee on NASA Scientific and Technological Program Reviews. In order to address diverse problems, the Committee has been authorized to establish ad hoc review panels, of which this--the panel to review the Numerical Aerodynamic Simulation program--is the fourth.

The charge to the panel, based on the Congressional request, is to provide:

- an examination of the stated objectives of the program including the projected short-term and long-term uses of the system

- an examination of the projected distribution of users and user requirements

- the merits of proceeding with a multi-processor system, a single processor, or some alternative architecture in terms of system capability and meeting user requirements

- an examination of provisions to make the system readily and easily accessible to the intended users

- milestones necessary to optimize a processing system network whether a multi-processor, a single processor, or some alternative architecture is used

- an examination of NASA's plans for the handling of proprietary and classified computations and their anticipation for down time.

The above six bullets which constitute the charge should be considered with regard to the adequacy of systems architecture, hardware, and software--the latter in view of NASA's intent to use early prototype supercomputers.

In carrying out this review, account should be taken of recent relevant NRC studies associated with computer science and technology, computational fluid dynamics, and aerospace system and engine design (such as the fifteen year projection of The Influence of Computational Fluid Dynamics On Experimental Aerospace Facilities).

It is expected that an on-site visit to the NASA Ames Research Center, responsible for development of the Numerical Aerodynamic Simulation facility, will be required.

It is understood that NASA will provide all information on the Numerical Aerodynamic Simulation Program necessary to the conduct of this review.

It is requested that the task be completed and the report be forwarded to the Committee on NASA Scientific and Technological Program Reviews no later than February 5, 1984.

Committee on NASA Scientific and Technological Program Reviews
Washington, D.C.
July 20, 1983

APPENDIX D

NASA/CONTRACTOR PARTICIPANTS IN BRIEFING SESSIONS

NAME	TITLE	CENTER
James O. Arnold	Chief, Computational Chemistry and Aerothermodynamics Branch	Ames
Frank R. Bailey	Manager, NAS Projects Office	Ames
William F. Ballhaus, Jr.	Director, Astronautics	Ames
Bruce T. Blaylock	Manager, Network Test Bed	Ames
Richard M. Brown	Manager, NAS Facilities and Operations Branch	Ames
Donald L. Ciffone	Deputy Manager, NAS	Ames
Raymond S. Colladay	Acting Associate Administrator for Aeronautics and Space Technology, OAST	NASA Hdqrs.
George S. Deiwert	Aerospace Engineer, CFD Branch	Ames
Peter F. Denning	Director, Research Institute for Advanced Computer Science (RIACS)	Ames
Palmer Dyal	Assistant Director, Astronautics Directorate	Ames
Randolph A. Graves, Jr.	Deputy Manager, Fluid and Thermal Physics Office	NASA Hdqrs.
Lawrence L. Hinman	Manager, ISC System Development, and Manager, Data System Technologies	Ames (G.E.)
Larry B. Hofman	Chief, Systems Engineering Branch (NAS)	Ames
Harry E. Jones	Manager, Long Haul Communications Subsystem	Ames
Paul Kutler	Chief, Applied Computational Aerodynamics Branch	Ames
Thomas A. Lasinski	Manager, Prototype Local User Subsystem Project (PLUS)	Ames
Dock W. Lee	Task Manager, System Engineering	G.E. ISC

Eugene Levin	Visiting Scientist	RIACS
Harvard Lomax	Chief, Computational Fluid Dynamics Branch	Ames
Joseph G. Marvin	Experimental Fluid Dynamics Branch	Ames
Parviz Moin	Aerospace Engineer, CFD Branch	Ames
Lewis L. Peach, Jr.	NASA/Ames Liaison Officer	NASA Hdqrs.
James N. Perdue	Manager, High-Speed Processor Subsystem	Ames
Victor L. Peterson	Chief, Thermo- and Gas-Dynamics Division	Ames
Frank S. Preston	NAS Systems Engineering	Ames
Cecil C. Rosen, III	Acting Director, Aerospace Research Division, OAST	NASA Hdqrs.
Donald N. Senzig	Chief, NAS Systems Development Branch	Ames
Marcelline C. Smith	Assistant Chief, Computer Systems Division	Ames
Walter K. Steiner	Comptroller's OAST Analyst	NASA Hdqrs.
Clarence A. Syvertson	Center Director	Ames

APPENDIX E

NAS USER INTERFACE GROUP

INDUSTRY

The Boeing Company
Detroit Diesel Allison Division, General Motors Corporation
Gates Learjet
General Dynamics
General Electric Company
Grumman Aerospace Corporation
Lockheed-California Company
Lockheed-Georgia Company
McDonnell Douglas Corporation
Northrop Corporation
Pratt and Whitney Aircraft Group
Rockwell International Corporation
Rohr Industries, Inc.
United Technologies Corporation
Vought Corporation

UNIVERSITY

Rutgers University
Stanford University
University of California, San Diego
University of Colorado

GOVERNMENT

National Aeronautics and Space Administration

Goddard Institute for Space Studies
Institute for Computer Applications in Science and Engineering, Langley Research Center
Langley Research Center
Lewis Research Center

Other

Arnold Engineering Development Center, U.S. Air Force
David W. Taylor Naval Ship Research and Development Center

National Center for Atmospheric Research
National Science Foundation
Naval Underwater Systems Center
U.S. Army Ballistic Research Laboratories
Wright Aeronautical Laboratories, U.S. Air Force

APPENDIX F

LIST OF NASA AND CONTRACTOR BRIEFINGS TO THE PANEL

September 1-2, 1983; Washington, D.C.
- Review of the Numerical Aerodynamic Simulation Program

November 2-4, 1983; Ames Research Center, California
- NAS Objectives and Related Activities
- NAS Program Description
- NAS Processing System Development
- Research Institute for Advanced Computer Science (RIACS)
- High Speed Processor Considerations
- Prototype Local User Subsystem (PLUS)
- Support Processors
- Long Haul Communication Subsystem
- Local Area Network Software
- NAS User Interface Group
- Office of Aeronautics and Space Technology NAS Coordinating Committee
- NAS Evaluation Test Codes
- Computational Fluid Dynamics Branch Interaction with NAS
- Reynolds-averaged Navier-Stokes Simulations
- Numerical Simulation of Turbulent Flows
- Projects of Applied Computational Aerodynamics Branch Requiring NAS
- Experimental Fluid Dynamics

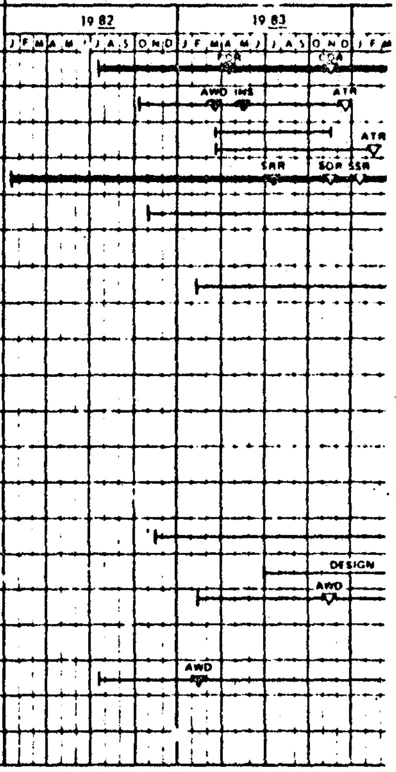
APPENDIX G

CENTER Ames Research Center
RESPONSIBILITY:
APPROVAL
ACCOMPLISHMENT F. R. Bailey

MILESTONE SCHEDULE

NUMERICAL AERODYNAMIC SIMULATION (NAS) PROGRAM MASTER SCHEDULE

	MILESTONES
1	NETWORK PROTOTYPE DEVEL.
2	NSP/DNS ACQ. & INSTAL.
3	S/W DEVELOPMENT SYS. INTEG. & TEST
4	INITIAL OPERATING CONFIG. DEVEL.
5	HSP-1 ACQ. & INSTAL.
6	S/W DEVELOPMENT SYS. INTEG. & TEST
7	NSP/DNS ACQ. & INSTAL.
8	S/W DEVELOPMENT SYS. INTEG. & TEST
9	EXTENDED OPERATING CONFIG. DEVEL.
10	HSP-2 ACQ. & INSTAL.
11	S/W DEVELOPMENT SYS. INTEG. & TEST
12	NSP/DNS ACQ. & INSTAL.
13	S/W DEVELOPMENT SYS. INTEG. & TEST
14	INTERIM FACILITY MODIFICATION
15	NAS FACILITY
16	SYSTEMS SOFTWARE CONTRACTS IOC / EOC
17	OPERATIONS SUPPORT CONTRACT
18	INTEGRATION SUPPORT CONTRACT
19	
20	



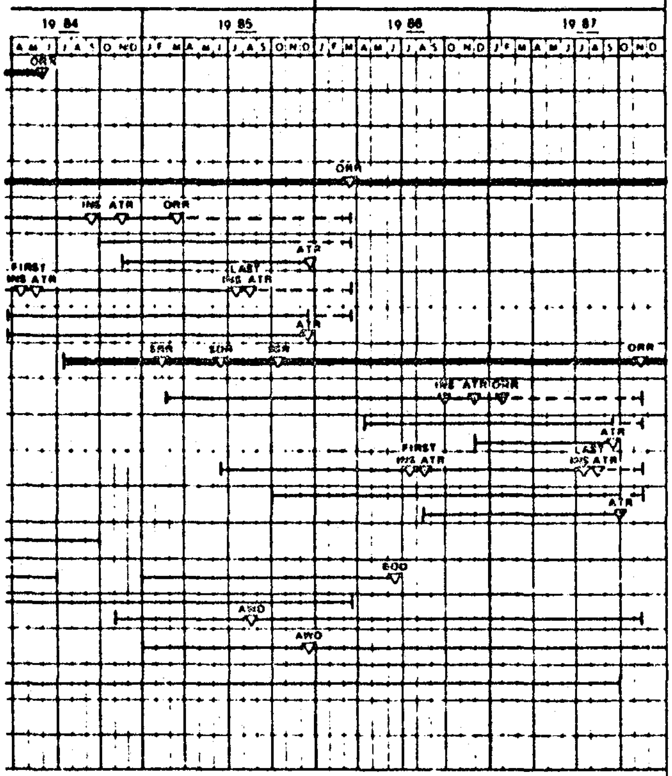
NOTES:

ATR - ACCEPTANCE TEST REVIEW
AWD - PROCUREMENT AWARD
BOD - BENEFICIAL OCCUPANCY DATE
DNS - DATA NETWORK SYSTEM
EOC - EXTENDED OPERATING CONFIGURATION
HSP - HIGH SPEED PROCESSOR
INS - INSTALLATION BEGINS
IOC - INITIAL OPERATING CONFIGURATION
NSP - NETWORK SUPPORT PROCESSING SYSTEM

ORIG SCHED APPR FEB 8 1983
(DATE)

LAST SCHED CHG 1CT 1, 1983
(DATE) (NO) (INITIALS)

STATUS AS OF OCT 1, 1983
(DATE) (INITIALS)



ORR - OPERATIONAL READINESS REVIEW
SDR - SYSTEM DESIGN REVIEW
SRR - SYSTEM REQUIREMENTS REVIEW
SSR - SOFTWARE SYSTEM REVIEW
- - - - UPGRADE

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, California 94035

NASA

APPENDIX H

S:200-4

January 13, 1984

JAN 1 8 1984

Dr. William R. Sears
Panel Chairman
National Research Council
Commission on Engineering and Technical Systems
2101 Constitution Ave., NW
Washington, DC 20418

Dear Dr. Sears:

It has been two months now since your Panel has reviewed the NAS Program. The Panel input has been very helpful, and I would like to thank you and the other members for your comments and suggestions. The purpose of this letter is to describe some actions that have been taken since the review.

To begin with, remote user access is receiving increased attention. A full-time slot has been allocated for a User Interface Manager within the NAS Projects Office, and several candidates are under consideration. The Long Haul Communications staff and organization have been strengthened, and a thorough study of potential remote user requirements is being completed for use in the Systems Design Review. We have advertised for a Long Haul Communications Manager and are interviewing candidates. A draft Long Haul Communications Policy has been completed. Recently, Marshall Space Flight Center released an RFP for a major contract to implement a new NASA Program Support Communications concept. The contract will be structured to allow for changing user requirements and should satisfy most of the NAS Long Haul Communications Requirements. Our updated requirements will be forwarded to Marshall by March 1, 1984.

Progress has been made on security issues. We have received a response from the DOD indicating that TEMPEST shielding is not required for the high-speed processors. This confirmation was required in order to proceed beyond the 15% design point on the building. A Security Requirements Study (including software) is about 50% complete. This work is being performed by SRI and will be used by the NAS Projects Office to produce a Security Requirements Specification. Our intention is to do all that is reasonably possible to safeguard the system and users' data while simultaneously minimizing user inconvenience and the impact on system performance.

Negotiations have been completed with Informatics General, Inc., who is now our System Software Contractor (SSC). A number of the key personnel are already on board and are preparing for the Software System Requirements Review. We have expanded the number of full-time equivalent Civil Servant positions for the activity to seven by the end of FY '84 (five on board now) and eleven in FY '85. Three new persons have joined the Project since the review in November, and we have selected two more who are scheduled to

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be on board by the end of the month. We will continue to add Civil Servant staff in key areas throughout FY '84.

The proposal for the High Speed Processor-1 has been received from Cray Research, Inc. Negotiations are in progress with contract award expected next month.

Implementation of four network protocol packages on the Network Test Bed is scheduled for completion by January 31. The NAS Processing System Network System Design Review has been rescheduled to late March to allow for the protocol selection and further development of other key issues such as security, remote usage, and completion of negotiations on the Cray-2 contract.

At this point, we are eleven months into the NAS Project implementation. The NAS Projects Office is still experiencing some of the growing pains associated with a rapid buildup of in-house staff and support service contractors and the establishment of management systems for project control. My assessment is that the Project is overcoming these growing pains, and we are certainly grateful for the insight and assistance of the Panel in helping us achieve our objectives.

Sincerely,

Wm F. Ballhaus Jr.

William F. Ballhaus, Jr.
Director of Astronautics

cc: R. H. Korkegi

END

DATE

FILMED

7-11-84

NTIS